European Hydro-Electric Power Development

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Canada's wealth in water powers is an asset to be seized upon and developed to the utmost advantage according to the expansion of the country. Recognizing such opportunity, or rather necessity, Canadian engineers entrusted with this development, while evolving their own principles of design and construction, naturally seek much inspiration abroad, especially in those countries which, historically at least, have led in their branch of work. Notwithstanding the many conditions peculiar to this country, especially that of climate, labor and of industry and commerce generally, the basic principles of the design, construction and operation of hydro-electric power plants are much the same as in Europe.

Viewed from the hydro-electric standpoint of engineering, Central

Chevres: General View of Station

Europe undoubtedly has led all other portions of the world, and it is there the engineer must go, even to-day, to obtain ideas as far ahead of America as are the European fashion. Switzerland is to the hydro-electric engineer what Paris is to the engineers of fashion.

It is not the least surprising that Switzerland, Northern Italy, Eastern France and the Austrian Tyrol should have attained this distinction, because they have grown into it by sheer necessity. These regions do not contain a pound of coal or other fuel in quantity, and it was to be expected that to the glacier fed streams and waterfalls the manufacturer and engineer would turn for his power. The result of this has been the

gradual development of the hydraulic turbine, the increase of its efficiency and the introduction and adoption of ingenious methods of application and control of water. And when electrical transmission became a settled factor, these countries were quick to seize upon its advantages in conjunction with their hydraulic works, with the result that in many respects they are, and continue to be, several years ahead of their competitors.

Through such means the design and the excellence of the hydraulic equipment manufactured in European shops and installed in their operating plants have reached a quality and an efficiency to which American builders have not yet, or only recently, partly attained.

On the electrical side, however, the conditions, the writer considers, are reversed and it seems to be generally admitted that American design and construction are to the front. There are, nevertheless, many points

Chevres: Interior of Station

in the European systems with which engineers on the American side of the water might do well to familiarize themselves. Among these might be noted the wide power distribution features, the great attention to detail, both technical and commercial, the very general use of small motors in what in many cases are almost household industries, and the popular education which has been directed by the Governments and power companies, looking to more universal use of electric power.

To present in such limited space any adequate description of typical installations in the several countries named would be well-nigh impossible, and it is the purpose of this paper to rather indicate some of the interesting features, both hydraulical, mechanical and electrical, in a few of the more important and recent plants.

In all the installations indicated there is indeed a great similarity in many of the electrical features, more especially because it is only very recently that long distance, high tension transmission, as we know it in

this country, has been attempted On the hydraulic side there is great dissimilarity, and on this account the many installatio... naturally fall into several distinct classes. The simp... st division is with relation to the hydraulic operating conditions, which for convenience has been divided into low, medium and high heads.

LOW HEAD PLANTS.

Low head plants as now designed in Europe are not comparable with those of twenty or even ten years ago, nor with the practice still prevailing in America. Water, the invaluable asset, is too preci...s to the European to allow any waste, such as even now is common in plants on this side of the ocean. To deal with large quantities of water as are involved in low head propositions has required bold design and bolder financing

Beznau: Interior of Generating Station

to obtain every foot-pound of energy throughout the year. Nowhere have more ingenious devices been employed to meet abnormal fluctuations in the level of head and tail water under low heads than in Switzerland, and from an hydraulic point of view this is the leading feature in the following.

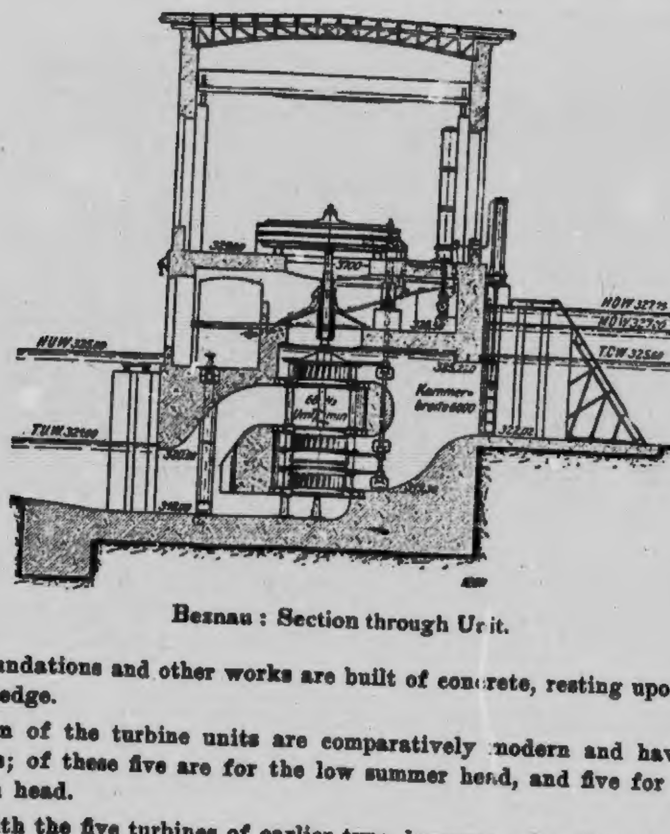
Chevres.—The Chevres plant is situated on the River Rhone, three miles below Geneva, Switzerland, and its history reads almost like an engineering romance, so various have been the changes and evolutions effected since its first construction in 1890.

In general the power works consist of a main dam provided with sluices for immediate control of head water, an entrance canal and intake service extending upstream from the dam and a generating station parallel to the river, extending down stream, having the water introduced on the shore side of the house. The sluice weir has six gates of the Stoney type, each 33 feet wide and 28 feet high, built between piers, each of which is 56 feet long and 10 feet thick. The Stoney gates are of

structural steel, counterbalanced and actuated with small hoists located on an overhead bridge, so adjusted that two men can raise or lower them by hand. Each gate weighs fifty tons and has three hundred and sixty tons against it when closed.

The dry weather flow of the Rhone at this point is about 4,200 sec. feet, occurring in winter, at which time there is a head of 28 feet; in summer the flow is as high as 32,000 sec. feet, when the head is reduced to 15 feet, or almost half.

The generating station is 450 feet long, and 41 feet wide, and accommodates 15 vertical type power units and three exciters, as well as a complete oil pumping and filter plant, a workshop and offces. All the build-



Beznau : Section through Unit.

ing foundations and other works are built of concrete, resting upon sandstone ledge.

Ten of the turbine units are comparatively modern and have four runners; of these five are for the low summer head, and five for winter or high head.

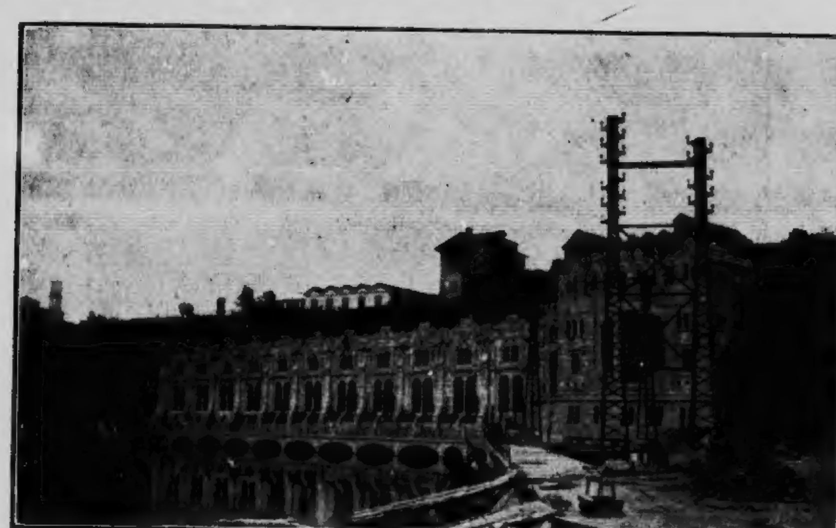
With the five turbines of earlier type, however, when there is a high head, that is, when tail water is low in winter, only the lower pair of runners is in operation, which when full open, develop 1,200 h.p. at 80 r.p.m. In summer, with high tail water level and low head, both pairs are in operation, when each delivers 400 h.p., or 800 h.p. together.

A peculiarity of these turbines is in the method of governing by a hydraulic servo motor, which provides that when the upper pair of wheels

is not working, only the lower gates are operated, and when both pairs are working, regulation is obtained by the gates of the upper pair only.

The electric generators installed at the different times are of the same general umbrella type, but are of various windings. Eleven units are two-phase, 750 kw., 2,750 volts at 45 cycles, five of which (earlier) have fixed fields, and six have revolving fields. Three units are 2-phase, 5,000 volts, and one is a D. C. machine of Thury 12 pole type, supplying current to an electro-chemical works nearby at 208 volts.

Perhaps the most remarkable features of this plant are in connection with the distribution and the large ratio of consumers to population served. The very general use of current in Geneva was evident in a short trip made by the writer, in company with the engineer, when a planing mill, a bakery, a jeweller's, a printing office and a chocolate factory were visited, in which from 2 to 15 h.p. were used. The large



Trezzo : General View of Generating Station.

number of takers under 2 h.p. was astonishing, and it may be noted that 113 of these small takers at 110 volts were using only 50½ h.p. altogether, while 189 at 500 volts were using 1,261 h.p. at the end of 1905. The average power of all motors was 1.2 kw. The total number of incandescent lamps in service at that time was 85,000. For the distribution of this power to 27 city and surburban localities, 698 transformers in 83 sub-stations are required, being the largest number of any plant in Switzerland.

Prices charged by the city of Geneva are as follows: For lighting, 16 c.p. lamps (70 watts), one cent per hour, with a large discount for a considerable number of lamps. For power, on flat rate, 1 h.p. at $64

Trezzo: Interior of Station.

per h.p. year, 10 h.p. at $43 per h.p. year, 20 h.p. at $32 per h.p. year, 50 h.p. at $28, and 100 h.p. at $22.40. These figures are based upon a ten hour day, with full advantage of the discount. A 24 hour day would increase the amounts by 50 per cent. Coal for steam power is about $7 per ton.

Beznau, River Aare.—One of the most interesting low head plants in Switzerland to-day is that situated on the Aare River, the Beznau Station. In it are constituted all the most recent improvements in the application of the water to the wheels, and in the wheels themselves are embodied the results of the experience of the past ten years, with plants operating low heads with large variations. This plant was completed and put into operation in 1904, and was quickly loaded up with consumers in the surrounding country.

The available fall varies between 10 and 15 feet, and, owing to this variation, the vertical turbine units consist of three runners 7 feet 6 inches diameter. One pair of runners is at the bottom, right and left, and the third above, discharging downwards into the draft chamber of the upper runner of the pair. At a medium head of 13 feet 1,000 h.p. is obtained on each unit at 67 r.p.m., using 890 sec. feet of water. The

Trezzo : Semenza "Umbrella" Insulator.

whole unit is supported by hydraulic pressure beneath a disc, so as to reduce the weight on the step bearing, and the small inequalities of this are further balanced by oil pressure from special pumps.

The power secured in these units varies between 7,000 and 11,000 h.p. for the whole installation of nine units.

The generators are of the umbrella revolving field type, 800 kw. each, 3-phase, wound to 8,000 volts at 50 cycles, and were built by Brown, Boveri & Company, of Baden. Local distribution is at the generating voltage, while long distance is at 25,000 volts up to 20 miles. The latter voltage was the highest in transmission operation in Switzerland at the end of 1905. The total length of transmission lines of this plant in 1905 was 70 miles, the number of localities served was 61, the population 250,-

000, the number of transformers 60, and stations 31, while the average power of motors served was 100 kw., in which respect this plant stands third in the country.

Prices of power are generally as follows: For lighting, 16 c.p. lamps, $4 each per year, continuous service. For motors on 10 hour basis, flat rate, 1 h.p. at $43, 10 h.p. at $39, 50 h.p. at $34, and 100 h.p. at $32. For 24 hour basis, 1 h.p. at $56; 10 h.p. at $49, 50 h.p. at $44, and 100 h.p. at $41.

Trezzo, Adda River, Italy.—The Trezzo plant is one of a series owned by the Edison Company of Milan, and has only been recently put in operation. The Adda River at this point (25 miles northeast of Milan) makes a horseshoe bend around a rocky hill, and the power project consisted of draining the river at the crown of the bend and placing the power house alongside of the rock cliff, discharging the water from the tail races through tunnels under the hill to the river below. The low head thus

Vigevano : Interior of Generating Station

obtained, only 24 feet, required vertical shaft type of units with low speeds and a corresponding large volume of water with many units.

Against the high cliff of the river, in the horseshoe, the power house was constructed, having its face parallel to the river flow opposite, yet almost square against the current on the approach to the curve; this arrangement provides ample water with minimum deflection, and at the same time produces a sweeping current to carry past debris, etc. The station is situated about 300 yards upstream from the sluice gates of the dam, and is a large and very handsome structure built entirely of stone.

It will be seen in the illustration that there are ten main water entrances, each 22 feet wide, and two exciter inlets. These represent as many units and the water in each, after passing screens and gates, enters a wheel pit with its vertical turbine, thence into the tail pit and common bay, about 300 by 60 feet, in the rear of the station. From this

point the water is conveyed by means of two tunnels beneath the cliff to the lower river. For a distance of 150 feet above the station and in continuation of the face of the water inlets, a series of ten overflow weirs is arranged to take care of slight inequalities in the river level.

The vertical turbines are Francis type, each of 1,500 h.p. capacity at 105 r.p.m.; the first six and the two exciter units are by Riva Monneret & Company, and the seventh is by Escher, Wyss & Company, of Zurich. Considerable use has been made of reinforcing steel in the concrete foundations and settings of these machines. The governors are connected by two stems to the gates. The generators are of 3-phase revolving field type, two at 50 cycles, and the remainder at 42 cycles, and are built by Gadda & Company, Milan.

Milan : Interurban Car, Third Rail System.

In the arrangement of switches, transformers, arresters, instrument boards, control, etc., this station is very complete and roomy, and the whole large wing at the end of the station is occupied by this apparatus. The distant control apparatus is, in itself, a very perfect arrangement, permitting complete operation from table switchboard to isolated apparatus in different compartments of switch and transformer rooms.

Four transmission circuits, three to Milan and one to Bergamo, are now in operation at 13,000 volts, carried on structural steel towers, known as the "Elastic" type. The function of these towers is that while rigid at right angles they will oscillate slightly in the direction of the line, creeping of the cables being prevented by guying at intervals. These towers are 40 feet high above the ground, built with two legs (channel section) 7 feet apart, and each leg set in concrete 5 feet deep; the top of each leg member carries two circuits. Insulators on these lines are of the

Paderno type, but are being partially replaced with a new design recently patented by Signor Semenza, consulting engineer of the company. This is a radical departure, but most simple, with qualities of insulation which are obvious. The design, which can be better illustrated than described, consists of the lower portion of a simple Paderno insulator, provided with a threaded top and side groove in which the wire passes: over the top is screwed an "umbrella" made of terra cotta about 12 inches in diameter. It is interesting to know that in the breakdown tests on this insulator, designed for 30,000 volts, the ratio between wet and dry conditions is nearly unity, viz., 122,000 volts for dry and 110,000 volts for wet. A feature of this new type is its small cost, the inexpensive, large upper part of the usual porcelain insulator being replaced by a simple, easily formed piece of terra cotta or other cheap material. As jokingly

St. Maurice : General View of Power Station.

pointed out by Signor Semenza, a new umbrella is, in this case, cheaper than an extra petticoat.

MEDIUM HEAD PLANTS.

There is perhaps not a great deal to be noticed in the plants of medium heads, say between 40 and 100 feet or more, as they are generally of types similar to many American installations. Two plants, however, have been chosen for particular features, which are especially interesting to electrical engineers.

Vigevano Plant, near Milan, Italy.—Milan, which may be said to be the electrical city of Central Europe, is developing such a tremendous business in power that the actual supply has been quite behind the demand, and the result is that the electrical companies in the field have

been using every means to increase their output by the exploitation of new hydro developments.

The new installation at Vigevano, on the Tessin river, 20 miles west of Milan, is a recent result of overburdened generating stations, and was placed in operation in 1906, and illustrates one of the latest types of hydro-electric stations to be adopted by Italian engineers.

Water for this plant is brought through canals three miles, to a fore-bay above the power station, having an overflow, screens and inlet sluices, to the steel penstocks, which are 6 feet 6 inches diameter, one for each unit. The penstocks are about 200 feet long and enter through the station wall into the tops of the wheel cases. As a generating station, the arrangement of this plant is ideal, and upon entering the visitor

St. Maurice : Adjustable Head Dam, Rhone River.

is impressed with the convenient and roomy arrangement. The turbine and generator units, five in number, are arranged abreast in a long hall, the two exciter units being at one end. At the same end is the switch-board, mounted on, and under, a floor, which is 6 feet above the main floor; the whole hall is about 340 feet by 40 feet. Alongside the gallery is an enlarged wing, containing all switching and transforming apparatus, the arrangement of which in convenient sequence, roomy spacing and isolation is very clever. In the introduction of these features the European practice in design within the past two years is quite marked.

The turbines are by Riva Monneret & Company, Milan, four units being installed at the time of the writer's visit on February 6th, 1906, and one being still in the shops. The type is horizontal shaft double Francis inward discharge, into a draft chest: the cases are exposed and form the termination of the penstocks. Each turbine unit works under

Olevano : 40 inch Penstock, 960 ft. head.

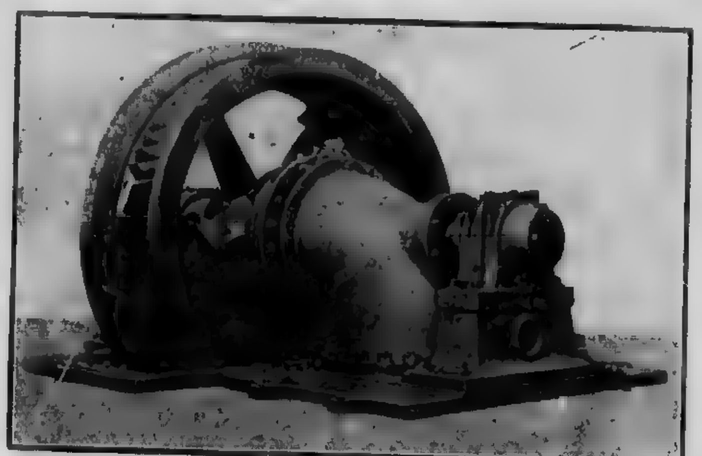
a head of 61 feet, developing 1,400 h.p., using 270 cubic feet of water per second. The governors are of a special oil type, recently perfected by the turbine makers, sensitive and very powerful for their size; the writer looked at the governors, especially to discover periodic hunting, while the station was running in parallel with a steam plant at Milan, but could see no injurious irregularities. The generators, by Gadda & Company, Milan, are directly connected, 3-phase, wound to 2,750 volts at 42 cycles.

Switch gear is fitted with table type instruments and distant control apparatus, so that the operators can at once see both instruments and machines. Current is stepped up to 25,000 volts and the transmission lines, comprising two circuits of 7 mm. wires, are carried on steel towers spaced 350 feet apart.

The power from this station is used in outlying towns to the north and west of Milan, as well as in the city.

The prices obtained by this company in the widely separated centres of consumption are based on a flat rate, and on a 24 hour day, average about $31 per h.p. year, with a minimum of $23 and a maximum of $44, depending on distance. The price of coal is about $7 per ton.

St. Maurice Station, Switzerland.—The St. Maurice-Lausanne installation, generating power from the Rhone east of Lake Geneva, and



Olevano : Impulse Wheel, 1,200 H. H. showing Nozzles, (case removed).

transmitting by direct current to Lausanne, 35 miles distant, has become world-famous as being the pioneer D. C. transmission system in commercial operation under the Thury patents.

Not only are the electrical features novel, but the hydraulic arrangements are also most unique, especially in the head works and in the hydraulic governors.

The Rhone is subject to great fluctuations in this region, being essentially a torrential river, and in the late summer and winter periods the flow runs to such a minimum that it is necessary to use special means to divert the water into the head works. For this purpose a permanent dam not being permitted or advisable, a device was resorted to whereby a moveable dam structure is let down into the river from an overhead bridge. The bridge is a steel Howe truss on stone piers; from the floor is suspended a series of hinged frames which can be lowered so that their lower ends rest in seats in the river bed. These frames are then filled

in with wooden stop logs to the desired height to divert the water to the inlet of the head canal alongside.

From the intake, water is conveyed by open cut and closed conduits, nearly two miles, to a forebay above the power station, whence three penstocks of 8 feet diameter, and about 1,500 feet long, lead to the turbines.

There are at present five power units in this station, each nominally 1,000 h.p. The turbines working under 110 feet head are of the Francis type horizontal shaft, with snail shell case, running at 300 r.p.m. Water is introduced from beneath the floor from the penstocks. Each turbine operates two direct current generators, and all five turbine units are governed in parallel from one governor, specially designed for this purpose.

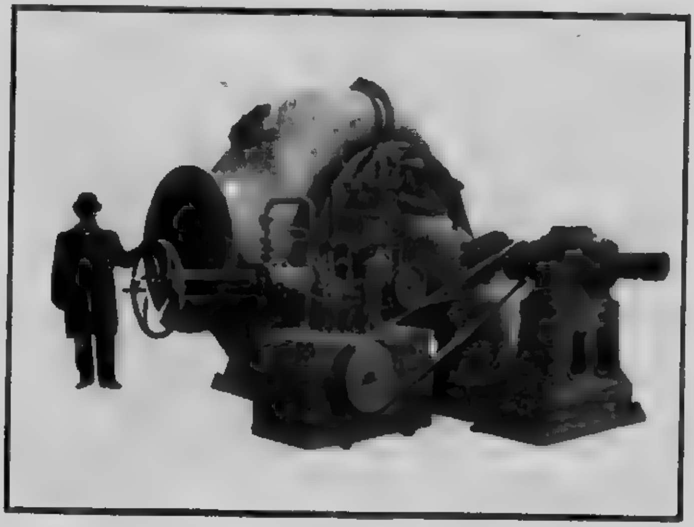
Olevano : High Tension Switches, (30,000 Volts).

The ten generators are of a special Thury type, giving 150 amperes at 2,300 volts. Connected in series the ultimate line voltage becomes 23,000 volts, and is transmitted over two wires to the step-down or distributing station in Lausanne, where by series motors the current is taken off to the secondary outlets. The electrical portion of this plant has been so often described in the technical press, especially the past three years, it is not the intention here to do so further. There are features of D. C. transmission and operation, however, which might be mentioned as of interest.

It is claimed for the Thury system that while the generating apparatus is much more costly than for alternating current—as much as 75 per cent. in excess—the switching gear and transformers, and buildings therefor, necessary for the alternating system are absent in the direct

current system; the total result being a cost very close to or perhaps less than the alternating.

In the transmission line, however, a great saving of first cost and operation exists, owing to cheaper insulators, less copper, smaller spacing of circuits on poles, cheaper and simpler lightning pr tion. The actual experiences with lightning in operating D. C. and A. C. transmission systems in France and Switzerland has, the past two years, been much in favor of the D. C. The St. Maurice-Lausanne line, which has been in operation for five six years, has seldom had a shut down due to lightning, and as this line and the new Moutier line, also singularly free, are in the Alps, where lightning disturbance is at its worst, it is claimed that their immunity from trouble has been entirely due to the system.



Gavet: 2,000 H. P. Spiral Francis Turbine, 190 ft. head.

HIGH HEAD PLANTS.

High head power installations are rapidly becoming the most numerous and important types in the Alps, for the generation of power. Certain localities in Switzerland have been specially developed in this respect, but there are also many such plants in the Alps, in France, Italy and Austria, as well as in other portions of the continent, especially where expensive fuel and a transmission market has offered remunerative investment.

Without enumerating the many plants, especially in the Central Alps, varying in head up to, in one instance, 3,140 feet, near Terri the highest in the world—the writer has selected a typical new Swiss installation, a new French plant in Savoy, and an Italian one south of Naples. Each of these has special features of interest.

The Olevano Plant, Near Naples, Italy.—The Olevano installation is on the Tusciano river about 50 miles south of Naples, has a capacity of 6,000 h.p. and current is transmitted to various towns en route to Naples, passing Vesuvius at its base. Its transmission lines suffered severely in the recent eruption. The uses are mainly for lighting and mixed power in small units, such as for fabric and textile weaving, machine and wood-working shops, but more than all for the macaroni factory, which is the flour mill of Italy.

The head water is brought about three miles by canal and tunnel to a forebay on the mountain side, thence down to the station in a steel

Gavet : Wood-Concrete Encased Poles.

penstock, forty inches diameter. There is now being used only about 70 sec. feet of water, under a static head of 960 feet. The penstock is about 2,000 feet long and is carried down the mountain on 65 concrete saddles. The lower end is horizontal and distributes to five power and two exciter units. The upper port'on of the penstock is of ¼ inch steel and the lower ⅝ inch.

In the generating station the five units at present installed are each of 1,200 h.p. output capacity. The waterwheels are of a special horizontal shaft, impulse type, manufactured by Piccard Pictet & Company, Geneva,

Switzerland. They are rated nominally at 1,400 h.p., run at 500 r.p.m., and each uses about 14 cubic feet per second of water. The runner, 4 feet 8 inches diameter, consists of two heavy cast iron rims, having the steel vanes set between: this is mounted in a spider attached to the shaft. The water is introduced through a pair of nozzles at 90 degrees with each other, which are formed in one casting bolted to the end of the supply pipe; the nozzles lie up to the inner periphery of the runner and the latter discharges outwards similarly to the Girard turbine. The discharged water is caught in a tail pit below and the whole (pit and runner) is covered with a casing. The nozzles are opened and closed by a bronze tongue or throttle deflecting within the opening on a shaft which is linked up to the governor.

In the earliest nozzles on this type of wheel, the manufacturers had formed the whole nozzle head and tongue of bronze, an expensive feature

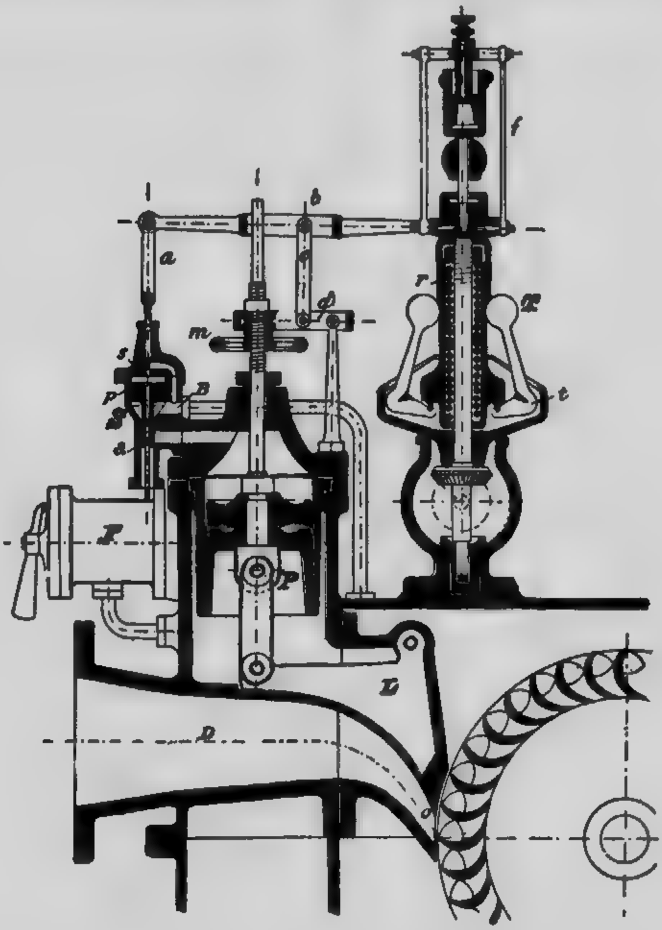
Vallorbe: Water Resistance Lightning Arrestor

in large units, especially when renewals are frequently required. Later types, however, such as the present, are built merely with bronze lips and tongue, as it is found that these—especially the lips—are cheaply and quickly renewed. The writer saw and obtained a photograph of the eroded nozzle from one of the wheels in this installation, which had been in use 12 months; it presented a good object lesson of the power of sanded water under high head, which forms one of the difficulties to be met with in the operation of this plant. It is to be noted that there is comparatively no erosion of the vanes of the runner under these conditions.

It is stated that in tests on these hydraulic units by the company, the following efficiencies were obtained: At full gate, 76 per cent.; at three-quarter gate, 73 per cent.; at half gate, 68 per cent.; at quarter gate, 62 per cent. The generators and electrical apparatus made by Westinghouse present no especially new features beyond the general modern practice of switching and isolation as designed by that house. The

generators are three-phase, wound to 3,000 volts, and static oil-cooled transformers step up to 30,000 volts to the line, consisting of two trunk circuits which are carried on one line of structural steel poles about 180 feet apart. The wires are 7 MM. copper, and are 24 inches apart.

Prices for power in the cities named vary according to amount and distance from generating station. At Salerno, 16 miles distant, 200 h.p.



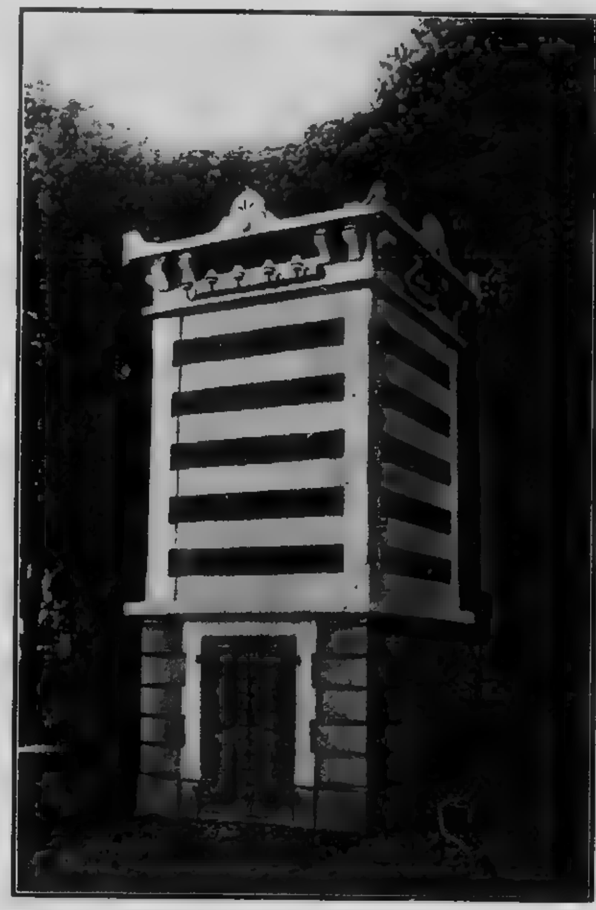
Vallorbe : Section through Hydraulic Govenor.

is sold for $25 per h.p. year, on a 24 hour basis; larger blocks of power are sold nearer Naples at $30 per h.p. at 24 hours. There are two consumers near Naples using 800 and 1,000 h.p. each. Coal at Naples is about $8 per ton.

Gavet Station, French Savoy.—This installation is situated on the Romanche river, and is in the heart of the French Alps. The distinctive features of this river are remarkable, for its flow is very small, being in

dry weather only about 300 sec. feet; while the flood discharge is thirty times as much. Its descent is very rapid, hence high heads prevail, and in the seven plants installed on twelve miles of its course 40,000 h.p. is developed. This river offers a notable example of the utmost development of mountain streams for power generation.

The power is used for numerous electro-chemical indutsries, including calcium carbide works, and especially the "electric-steel" works of



Vallorbe, Artistic Transformer House

Keller, Leleux & Company at Livet. At Livet is also located the municipal plant for Grenoble. A transmission line from the latter, 24 miles long, to Grenoble, has a considerable portion carried on wooden poles incased in from 1 to 2 inches of concrete. Unique as this is, it appeared to have given fair satisfaction in the three years' operation before the writer saw it.

The Gavet station, completed in 1906, is 16 miles from Grenoble and has an output of 5,000 h.p. at the lowest stage of the river. The head works are very ingenious, having besides the dam, several weirs and settling basins for the purpose of freeing the water of gravel, sand and silt, which is carried in great quantities in mountain streams. The flume or tunnel to the power station is 7,000 feet long and about 10 feet square.

The tunnel terminates in a small covered forebay high up the face of the cliff above the station, having outlets for two penstocks and one spill-

Vallorbe: General View of Station, 770 ft. head

way. The penstocks follow down the cliff, and are 7 feet diameter, about 500 feet long, and each branches to the three main and two exciter units at the rear wall of the station.

The station is of rubble stone, having a generating room, commodious switchboard gallery, wire ducts, transformer and arrester rooms. The writer had the pleasure of visiting the plant on February 14th, 1906, with

the consulting engineer, M. Boissonas, of Geneva, who pointed out many of the new feautures.

The turbines develop 2,000 horse-power each, working under a head of 190 feet; they are of the horizontal shaft, single spiral Francis type, built by Piccard Pictet & Company, of Geneva. The distributor gates are swivel style, with an actuating gates ring carried on arms fitted with springs, to positively take up lost motion. The governors are by the same makers, arranged with a new device on the fly balls, to stop petty vibrations. The main shafts have flywheels and Zodel flexible leather link couplings.

The generators are by Schneider & Company, Champagne, revolving field type, three-phase, 4,000 volts, 231 amp. per phase. The transformers step up to 26,000 line voltage the same as at the Avignonet station, with which this station will at times be run in parallel, 24 miles distant. The line is at present carried on wooden poles.

Good quality steam coal in Grenoble costs about $5 per ton. The prices of the Societe Grenobloise are, in general, as follows: For 24 hours' service the average prices (variable on account of distance) are, say for 100 h.p., $30 per h.p. year, and for 500 h.p. about $26 per h.p. year. In 500 h.p. quantities prices run down as low as $18 for transmitted power and even to $12 at the station. This company has now 15 year contracts for about 15,000 h.p., with some customers 100 miles distant.

Vallorbe Development, Switzerland.—Vallorbe is a small city in Canton Vaud on the Orbe river, north of Geneva, and two miles from the French frontier. The river empties from Lake de Joux, which is 800 feet above the valley, through an underground passage, and commences its course as an open river from a gigantic bubbling spring.

The Vallorbe plant has been in operation since 1904 with five units; space and connections are arranged, however, for three more, while ultimate extensions will provide for a total of about 12 units if sufficient water can be secured. The present output of this plant is 5,000 h.p.

Hydraulically this development is most remarkable, owing to the nature of the water supply. Lakes de Joux and Brenet have six and seven surface outlets respectively, but the main discharge is the subterranean river, which forms the Orbe. In order to get sufficient water, then, all the small surface outlets were dammed, and the lakes were formed into a huge reservoir, in which the concessions permitted the fluctuation of the level within limits of 12 feet, artificially controlled. At certain periods of the year these lakes have regularly risen a number of feet, according to a law determined by observations extending over many years. This increase is now partially secured by the new works, and is held up for power purposes. The subterranean flow, however, still proceeds. Hence the development presents the unique feature of being dependent entirely on storage water or such as can be stolen from the natural outlet.

The water taken at the intake in the lake, after passing racks and gates, is carried by means of a rectangular concrete lined tunnel to a

point on the lower hillside, where a forebay and head house are located. The tunnel conduit is 6 feet 6 inches wide, 7 feet high and about 8,700 feet long.

The forebay works can be seen high up the mountain side. Water issuing from the tunnel first passes a coarse rack, enters a chamber having an overflow weir with adjustable crest, thence passing head gates enters the penstocks. Overflow water spills into a large chamber from which steel pipes carry it down the slope. The penstock varies in diameter from 48 inches at the top to 40 inches at the station, the respective thicknesses of plates being 5-16 inch and 13-16 inch, while the distributor portion within the building is 1 inch. The total length of penstock is about 2,000 feet; it is carried on concrete piers with heavy anchorages and there are four expansion joints.

The two spill pipes are about 2,400 feet long, about 3 feet diameter, 7-16 inch plate, and with rivets counter-sunk on inside. These have several expansion joints and automatic air entry valves. They discharge water into the river below the power house.

In a plain concrete building are now installed five 1,000 h.p. units and two exciters, operating under a head of 770 feet. These units are contained in a room 160 feet long and 40 feet wide, while in a central wing are located the busses, switches, switchboards and arresters.

The waterwheels are by Escher, Wyss & Company, having single nozzles with one runner. A feature of this wheel is its automatic hydraulic regulator. In plants of this pressure, European builders are using filtered water from the penstock instead of oil as a medium. This involves a mechanical filter on the governor to insure clean water. Escher, Wyss have what they call a "revolving filter," F, which can be worked by hand. The cycle of operation from the fly balls to the relay valve, with its fine adjustment to prevent "racing," through the level system to the regulating valve G thence to the main cylinder and piston P, and to the throttling lip L, can be readily followed. The generators are built by the Oerlikon shops and are 3-phase, 50 cycles, 13,500 volts at 375 r.p.m.; they are connected to the wheels with Zodel couplings. The switching is specially interesting, owing to the wide system of distribution, but is simplified by having no transformers. Instrument pedestals of American type are installed, and the chief operator from his gallery can easily control all operations of the station. A unique arrangement of hydraulic jet lightning arrester is installed on a floor above the gallery. This combines a horn type arrester with a water resistance together with a choke coil and metallic ground wire.

For the distribution of this power and that from the lower station there is planned a network of over 250 miles of line, the farthest point served being about 50 miles distant. A characteristic is the widely scattered network of power service. The total population in the localities is about 100,000, the number of localities or communes designed to be served is 212, with 235 transformer stations. This is a striking example of the

Roman Plant at Tivoli: Penstocks under 165 ft. head.

extensive detail of distribution which European companies are now carrying out, and both the people and the power companies of Ontario can at the present time benefit materially by following Swiss lead in this respect.

The power in these places is used for lighting, street railways, cement and brickyards, all manner of agricultural needs, such as churning, etc., watch-making, weaving and miscellaneous shops and industries.

Small transforming stations, of standard design, about 10 feet by 12 feet inside and 27 feet high with 3 floors, are erected in many localities. These are built of brick or concrete and are cheap and neat in appearance. Some in city streets and parks are most artistic.

Prices are as follows: For light, 16 c.p. lamps, from 400 to 800 hours per year, \$3.60; over 800 hours, \$4.40. For heating, 8 cents per kilowatt hour. For motors, flat rate, on 11 hour basis, less than 1 h.p., \$60 per year; 1 to 2 h.p., \$40; 9 to 11 h.p., \$37; 25 h.p., \$33; 50 h.p., \$30; 100 h.p., \$29. On 24 hour basis add 25 per cent. to above figures. For motors on meter rates, from 2.5 cents per kw. hour at 1 h.p., down to 1.4 cents at 100 h.p.